

THE ECONOMICS OF NEOS

NASA's Ames Research Center, in its role as partnerships lead for NASA asteroid redirect robotic missions and as a supporting Center for the Asteroid Grand Challenge, responded to increasing interest in near-Earth objects (NEOs) by holding a workshop entitled 'The Economics of NEOs' on the 6th and 7th of September 2014. The workshop was intended to serve as a catalyst for discussions and to foster collaborations between industry, academia and government. This document serves as a summary of the discussions which took place within three sessions and their respective table discussions; Session One: Background and Motivation; Session Two: Economics of NEOs; and Session Three: Policy and Legal Frameworks. This document is a collection of observations by individuals and does not express the consensus view of all participants; it does not express US Government or NASA policy.

Key Workshop Findings:

1. Great synergies exist between planetary defense, scientific research, **space exploration**, and commercial space activities—including mining of minerals and volatiles—that could be strengthened through public-private partnerships.
2. There is a need for a space-based telescope designed to be part of a broad survey detecting and characterizing asteroids, and for the benefit of all stakeholders in the NEO community.
3. There are a number of technology barriers—particularly relating to long-distance robotic mining and in-situ resource utilization—but many participants are confident they can be overcome in the near future **with focused efforts**.
4. Economic barriers exist because the perceived and actual risks for long-term returns on monetary investment are deemed high. However, private companies in the trade indicate near-term revenue streams **on relevant products** are already being actualized.
5. Certain high-net-worth individuals have the necessary capital and incentive to spend on legacy-building projects which include the prospect of mining NEOs.
6. Ambiguities in applicable international law needs to be addressed with regards to NEO activities. This is equally important whether or not such activity is scientific or commercial in nature.
7. Government space agencies, international regulatory bodies, private companies and academic institutions might work together closely on a long-term strategy regarding NEOs specifically, enabling the industry to grow in a stable, supporting environment.
8. The private sector could be more vocal about NEO activities with respect to desired reforms in applicable laws and policy as well as short-term investment opportunities.
9. The development of a legal and policy framework may help enable a commercial space mining industry.

Introduction

The 2013 Chelyabinsk meteor demonstrated that **uncertainties still exist in our understanding of near-Earth objects (NEOs)**. Although the impact rate for dangerous asteroids is low, the consequences of such an event are severe. Over the past two decades, **NASA has established a program which supports several projects to detect and research NEOs**. However, further efforts are needed to effectively explore the scientific and technological means to detect, track, characterize, mitigate and communicate potential threats. Although asteroids are viewed as hazardous, they are also seen as objects of opportunity. Today multiple actors in the private sphere are seeking to mine these bodies for commercial purposes. The economics and regulatory questions that arise from such pursuits were at the core of the workshop: The Economics of NEOs.

Session 1: Background and Motivations

The motivations behind the interest in NEOs are many and varied. The first session of the workshop delved into these motivations and identified places where goals are aligned, and where there is significant project overlap. In no particular order, the five main motivators for the exploration of NEOs are: i) scientific exploration; ii) planetary defense; iii) resource extraction; iv) to provide material support and resources for missions beyond low Earth orbit (LEO); and v) to provide destinations for the human exploration of space. These are addressed accordingly.

Scientific Exploration

Astronomers were the first people to explore asteroids remotely and often used observatories funded by private philanthropists. Today, largely thanks to projects run by government and academia, science is still a motivation for missions to explore NEOs. Asteroids can teach us about the formation of the Solar System and the

early history of the Earth and Moon. Hence, telescope surveys, in-situ analysis and sample return missions all continue to be of real interest to the scientific community.

Planetary Defense

While unlikely, **an asteroid** impacting Earth with devastating consequences poses a real danger—one which governments and the scientific community have begun to take seriously. Thus, **programs** have been created by NASA and other agencies to catalogue and track NEOs. These include the NASA Asteroid Grand Challenge and the NASA NEO **Observations** Program. Some of these programs have demonstrated increasing opportunities for participation by citizen-scientists in tracking and characterization.

Resource Extraction

Although typically relegated as ‘pure science fiction,’ the prospect of mining NEOs for minerals and volatiles—whether transported to Earth or for utilization in space—has begun to be featured in more

serious terms. Key motivators include: i) profiting from the sale of valuable minerals back on Earth, ii) supplying a growing population with increasingly rare minerals; iii) protecting Earth's environment; and iv) the creation of infrastructure that would support deep space missions and a financially viable space economy.

Support for Missions Beyond Low Earth Orbit

Earth's gravity well makes any mission beyond LEO such an expensive endeavor that conference attendees felt it unlikely that we will ever establish a robust presence in deep space without changing the current paradigm. If asteroid materials could be mined and processed, it would enable much lighter spacecraft to launch inexpensively and refuel, repair—and even one day be constructed—in space.

Human Exploration of Space

The NASA Asteroid Redirect Mission (ARM) suggests that an asteroid is seen as the agency's next destination for human space travel and the first destination beyond LEO since the Moon. In addition to providing a destination for the next beyond-LEO human spacecraft missions, such a mission will provide vital information on the makeup of asteroids and is intended to demonstrate techniques that could be used to deflect hazardous NEOs.

Session 2: Economics of NEOs

The second session focused on NEO activities by NASA and NEO prospective activities by commercial companies. Representatives from NASA and several private companies presented an overview of their projects and, in the case of the commercial players, presented business cases. The principal topics were: i) the need for comprehensive asteroid identification and characterization; ii) profitability in the short-, mid- and long-term; iii) the case for the sale of asteroid material on Earth and the case for the use of such materials in space; and iv) the case for initially targeting volatiles.

Asteroid Identification & Characterization

A combined effort to identify asteroid candidates which interest community would help prevent duplications of effort. The NEO arena would benefit from significantly more information about asteroids' location, size, and composition. Workshop attendees felt that ground- and space-based telescopes need to be built and used specifically for this purpose.

If government has a scientific planetary defense interest, it might invest alongside a company with an interest in resource extraction. The partners could share the detection infrastructure and equipment. In this regard, the community as a whole might follow the example of one aspect of NASA's Asteroid Redirect Mission: the intention to "pursue a target of opportunity that benefits scientific and partnership interests,

expanding our knowledge of small celestial bodies and enabling the mining of asteroid resources for commercial and exploration needs.”¹

Short-Term Profitability

As the private space industry matures, companies in all spheres are beginning to make real profit in space. The key for asteroid mining ventures is to begin realizing profit along the path to mining an asteroid because the market and infrastructure may develop slowly. Revenue obtained through developed intellectual property and other stepping stone projects can be used to fund a longer-term goal. Several companies claim already to be earning significant short-term profits. It was also noted that insurance policies can encourage nervous investors to begin supplying capital.

Medium-Term Profitability

Many players hope the government will play the role of “first customer”. This was seen to be successful in the development of commercial aeronautics and, more recently, in the Commercial Cargo and Crew Program for transport to Low-Earth Orbit. While the demand for refueling stations in orbit doesn’t currently exist, an administration like NASA might offer to purchase a specified quantity of a basic resource like water in space on a certain date for a set price. This would give investors more confidence in the medium-term profitability of the industry.

Long-Term Profitability

Commercial companies planning to exploit space-based resources have a common desire to extract and sell minerals from NEOs. Some plan to work with water. But water is not currently very valuable on Earth, and organizations hoping to sell asteroid resources back home are interested in rarer and more expensive minerals as well.

Although some companies plan to pursue both markets, ultimately, there are two different approaches advocated within the industry. Some believe that true profitability lies in selling rare elements back on Earth, while others insist that this is not economically feasible and that the principal reason for extraterrestrial mining must be to support beyond-LEO travel. In each scenario, infrastructure, customers, and resources harvested would be different. There is currently a fierce debate as to which of these two paths is the most economically viable and there is no clear consensus within the community. Some of the pros and cons raised at the workshop are listed below.

Resource Extraction: Return to Earth

Pros:

- Asteroids have different elemental make-ups to the Earth’s crust so we may find rare elements in abundance;
- We are running out of resources to support our expanding population; and
- Moving mining to asteroids will help create an environmentally pristine Earth.

¹ NASA, 'Asteroid Initiative Opportunities Forum – Update on Asteroid Redirect Mission', http://www.nasa.gov/sites/default/files/files/AsteroidRedirectMission_Update_Panel.pdf, 2014.

Cons:

- It will be very expensive to bring minerals back to Earth;
- The fabled “platinum asteroid” is unlikely to exist;
- We are not yet seriously running out of essential minerals; and
- We still haven’t explored the 70% of total mineral deposits under the oceans.

Resource Extraction: Use in Space

Pros:

- It will be necessary to supply fuel and provide construction and repair services in space for a robust space industry to become economically viable;
- The Earth’s gravity well makes launching materials, fuel, and parts very expensive;
- Supply depots in orbit and on asteroids and the Moon could make missions to other Solar System bodies much cheaper;
- The establishment of propellant depots at key locations in near Earth space would enable reusable transportation in space to become viable; and
- We must demonstrate that resources can be extracted and processed close to Earth before we begin trying to build self-sustaining communities on more distant bodies such as Mars.

Cons:

- There is currently no customer for resources in space;
- There are significant technology barriers for complex in-situ mineral processing; and
- There is no infrastructure or design standard to support this kind of system.

Water as First Target

A common theme was that water is the most feasible resource to target first. Water, and the elements from which it is comprised, are abundant, useful, and very expensive to launch from Earth. Extracting it from asteroids would allow it to be used for propulsion, water and oxygen for life, and various mineral processing schemes.

Government as First Customer

Since there is not currently a market for resource supply in space, it was suggested that the government might act as the first customer. By guaranteeing a price and quantity for purchase of water in space by a certain date, it would allow private companies to raise capital based on the concrete projected returns and thus jump-start the industry.

Session 3: Policy and Legal Frameworks

Session 3 focused on questions of national and international law, ownership rights and the role of policy makers. While it was generally agreed that current international treaties—principally the 1967 Outer Space Treaty and the 1984 Moon Agreement—are insufficient for the current environment there was little consensus on a path forward. Key questions involve i) the role of government, ii) the need for legal certainty, iii) whether to amend or rewrite current policy, iv) roles and responsibilities governments can assume to encourage the industry, and v) the need for industry leadership.

The Role of Government

National and international governing bodies are in positions either to help birth the nascent asteroid mining economy or make it close to impossible for it to succeed. Participants felt that government policy might encourage business ventures by removing restrictions, granting tax incentives and by providing the security early investors need in the form of guaranteed business, insurance and public-private partnerships.

However, if governments insist that comprehensive policy be enacted before any commercial activities involving asteroids takes place, it might result in a stillborn industry. A fundamental question raised about the role of the government is whether something needs to be considered forbidden unless it is expressly authorized.

Attendees sensed a mismatch between the pace of innovation and the government's ability to consider new legislation. In general, the business representatives at the workshop believed that if asteroid mining is not forbidden, then it should be considered legal. Some policy analysts and lawyers were more cautious however, advocating lobbying of lawmaking bodies and the creation of a robust commercial space policy before companies embark on major endeavors.

Adding to the uncertainty is the fact that although the Outer Space Treaty doesn't explicitly prohibit exploitation of space resources, not all countries agree with this interpretation.

Legal Certainty

The question then becomes whether we need more legal certainty or whether the ambiguous legal environment is actually more conducive to a new commercial enterprise as policy can be written with real rather than hypothetical circumstances in mind.

Amend or Rewrite?

This led to a discussion of the current international legal framework. Since we have a number of international treaties in place already, the subject of whether we can amend the old laws or whether we need to write completely new treaties needs to be broached. Either way, it is unclear what body would lead the push for change. Countries at the forefront of the issue might begin by creating domestic policy which others could follow until there is enough traction to begin tackling the big international treaties.

A Different Era

Current international space laws were written for a very different era. Treaties written in the 60s do not reflect the current entrepreneurial environment but rather Cold War-era geopolitical concerns. Furthermore, because of the pristine nature of the space environment itself, interpretation of the law often focuses on the restrictive elements of the wording, rather than that which enables the activities to proceed. This makes it difficult for organizations to know how to proceed.

Discussion of Possible Government Actions and Objectives

As demonstrated above, there is little consensus on how to proceed. Questions still to answer involve—among other things—the ambiguous legal environment, ownership rights and interpretation or amendment of the Outer Space Treaty, but it is unlikely many will be resolved soon. There are, however, initial steps governments might take to help this fledgling ecosystem today. Listed below are a number of specific governmental responsibilities and actions discussed at the workshop. These might help the NEO community succeed in an environment where there is little infrastructure, few existing customers and a sometimes ambiguous or outdated collection of national and international laws.

Possible government objectives:

- Enable development and success of industry;
- Nurture and support nascent industries;
- Focus on national programs which are outcome oriented;
- Regulate where necessary;
- Bear necessary costs that are too high for the fledgling industry; and
- Act as first customer to guarantee market in a new field.

Possible government actions:

- Provide geoscience information, e.g. mapping and analysis;
- Conduct research and development;
- Institute favorable property rights and mineral claim regimes;
- Adopt a “no taxation in space” policy during the industry’s infancy;
- Develop specific processes to deal with regulatory issues as they arise;
- Commit to purchasing services on a specific date for a specific price; and
- Allow private companies to use their communications capabilities.

Industry Leadership

To alleviate the fears of companies and investors, the workshop discussed the idea of a charismatic figure or organization that might fight for the vision of commercial space and help guarantee the future of the industry whichever of the above paths are followed. Some of the attendees went so far as to argue that legislation restricting our ability to explore and settle the universe is a crime against the future.

Conclusion

The Economics of NEOs workshop was an important and successful endeavor. Over 100 guests from across this emergent field attended, representing—among others—academia, the scientific community, international governments and aerospace agencies, commercial and industrial leaders, policy analysts and lawyers, all of whom are poised to play pivotal roles in the future of public and private space.

The quality of discussion allowed the attendees to isolate the most salient challenges and opportunities presented to the NEO community. Thanks to serious and thought-provoking presentations, questions, and table discussions, participants are better prepared to meet the upcoming challenges and opportunities head on.

Standing on the threshold of a completely new chapter of the space age - one in which planetary defense, solar system exploration, and resource utilization converge, participants of the economics of NEOs will no doubt play an important role in shaping its future.

